CHAPTER 4

ELECTRICAL AND HYDRAULIC SYSTEMS

The electrical and hydraulic systems are major components designed to perform a variety of functions that support the operation of equipment. These systems control starting, charging, braking, steering, lifting, and the movement of all attachments. This chapter covers the basic components of the electrical and hydraulic systems used in automotive and construction equipment.

ELECTRICAL SYSTEMS

Proper performance of pre- and post-operational checks and operator maintenance requires a basic understanding of the electrical systems used on automotive and construction equipment. The basic components of the electrical system are the following: a storage battery, a charging system, starting circuits, a lighting system, and gauges.

STORAGE BATTERY

The storage battery is the heart of the charging circuit. The type used in automotive, construction, and weight-handling equipment is a lead-acid cell type of battery. This type of battery stores energy in a chemical form. It is not a storage tank for electricity.

The battery acts as a stabilizer for the voltage of the electrical system and may, for a limited time, furnish current when the electrical demands of the vehicle exceed the generator output. The battery produces a flow of direct current when lights, starter motor, or other current-consuming devices are connected to the battery posts. This current is produced by a chemical reaction between the active materials of the plates and the sulfuric acid of the electrolyte.

Part of your prestart and operator maintenance responsibilities are checking the battery water level and ensuring the battery terminals are tight and free from corrosion. You can clean a battery thoroughly by using a stiff brush and a water and baking soda solution. If the battery terminals are corroded, disconnect and clean them. Clean the battery posts and the inside of the connectors so they make good electrical contact. After cleaning, you should rinse off the battery with clean water. If the battery fails to supply sufficient power to turn the starter, document it and turn it in.

Battery Construction

A typical lead-acid storage battery is shown in figure 4-1. Like most batteries, it consists of a molded container with individual cell compartments, cell elements, cell connectors, cell covers, terminal posts, and vented filler caps.

The container is made of molded hard rubber, plastic, or bituminous material. It must withstand shock and vibration as well as the heat of the engine compartment, if so located. Each cell compartment has rests to support the elements and space for an adequate supply of electrolyte. An area between the element rests allows any material from the elements to settle without contacting the elements and causing an internal short.

The cell elements contain two types of lead plates, known as positive and negative. These plates are insulated from each other by suitable separators made of microporous, nonconductor material (usually porous rubber or spun glass) and are submerged in a sulfuric acid solution (electrolyte).

Batteries are designed with a single cover that extends over all cells. In many batteries, only the filler

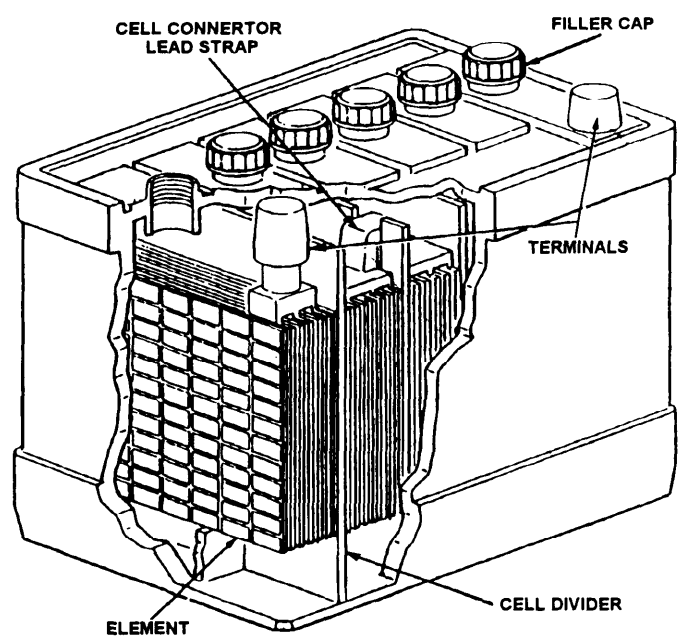

Figure 4-1.—Typical storage battery.

caps and the terminal post protrude from the cover. In other batteries, only the filler caps extend above the cover and the terminal posts extend through the side. The latest design of batteries is the so-called maintenance-free batteries that provide no means of checking the electrolyte or water level.

Battery Capacity

The capacity of a battery is measured in cold cranking amps (CCA). The CCA capacity is equal to the product of the current in amperes and the time in hours during which the battery is supplying this current when cranking a cold engine. The ampere-hour capacity varies inversely with the discharge current. The size of a cell is determined by its ampere-hour capacity. The capacity of a cell depends upon many factors. The most important of these factors are the following: (1) the area of the plates in contact with the electrolyte; (2) the quantity and specific gravity of the electrolyte; (3) the type of separators; (4) the general condition of the battery (degree of sulfating, plates buckled, separators warped, sediment in bottom of cells, etc.); and (5) the final limiting voltage.

CHARGING SYSTEM

The charging system performs two jobs: (1) it recharges the battery and (2) it generates current during operation. The two types of charging systems used on automotive and construction equipment are a dc charging system (fig. 4-2, view A) or an ac charging system (fig. 4-2, view B). Both systems generate an alternating current (at); however, the difference is the way they rectify the ac current to direct current (de) for charging the battery.

Dc Charging System

A dc charging system has a generator and a regulator. The generator supplies the electrical power and rectifies its current mechanically by using commutator bars and brushes. The regulator performs three jobs: (1) it opens and closes the charging circuit, (2) it prevents overcharging of the battery, and (3) it limits the output of the generator to safe rates.

Ac Charging System

An ac charging system has an alternator and a regulator. The alternator is really an ac generator. Like the generator, it produces an ac current but rectifies it electronically, using diodes. Most alternators are more compact than generators of equal output and supply a higher current output at low-engine speeds. The regulator in an ac charging system limits the alternator voltage to a safe, preset value.

Charging System

All charging systems operate in three stages: (1) during starting, the battery supplies all load current; (2)

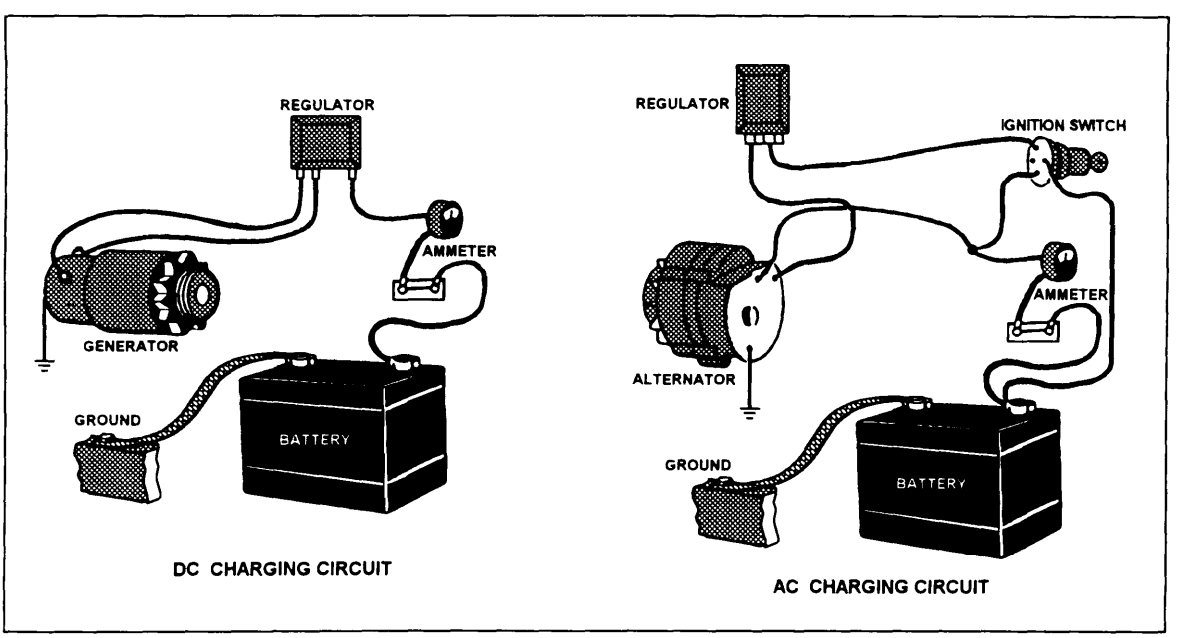

Figure 4-2.—Charging systems.

during peak operation, the battery helps the generator supply current; and (3) during normal operation, the generator supplies all current and recharges the battery.

In both electrical systems, the battery starts the electrical circuit that supplies the spark to start the engine. The engine then drives the generator or alternator that produces current to take over the operation of the ignition, lights, and accessory loads.

The battery also supports the generator or alternator during peak operation when the electrical loads are excessive. But once the engine is started the generator or alternator is the "work horse," providing current to the ignition and accessory circuits. The generator supplies current as long as the engine is at speed and running. When the engine slows down or stops, the battery takes over part or all of the load.

STARTING CIRCUITS

High voltage is often necessary to ensure sufficient starting power due to the high compression ratios of some diesel engines. Three systems are used to increase either the voltage or amperage to accomplish this task These are parallel, series, and series-parallel systems.

Parallel System

An example of a parallel system, as shown in figure 4-3, view A, is two 12-volt, 200-amp batteries are connected from the starter to the positive terminal of one battery to the positive terminal of the second battery. The negative side of the batteries are connected from the ground to the negative terminal from one battery to the negative terminal of second battery. This system provides 12 volts and 400 amps, providing more amperage for starting.

Series System

An example of a series system, as shown in figure 4-3, view B, is two 12 volt, 200-amp batteries are connected from the positive terminal of one battery to the negative terminal of the second battery. The remaining positive terminal is connected to the starter and the remaining negative temninal is connected to the ground. This system provides 24 volt and 200 amps, providing more volts for starting.

Series-Parallel System

A series-parallel system provides a series connection of the batteries for starting and a parallel

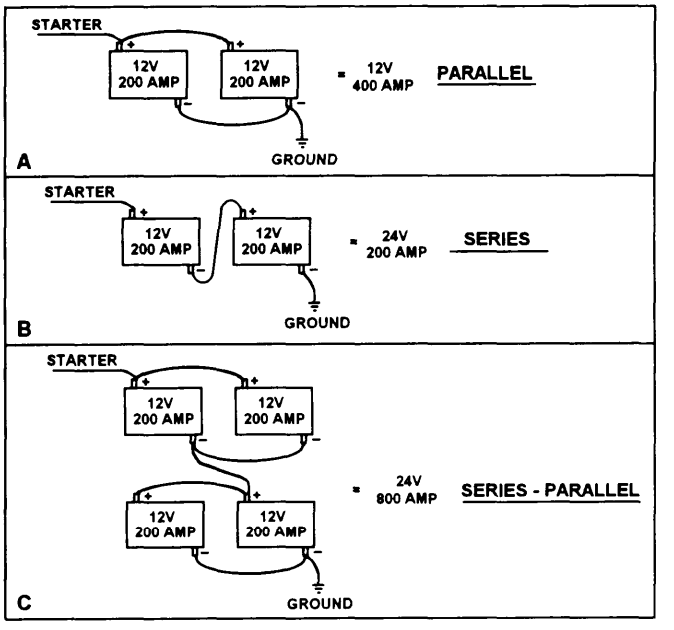

Figure 4-3.—Starting circuits.

connection for normal operation. An example of a series-parallel system is when two sets of parallel batteries, as shown in figure 4-3, view C, are connected in series and the negative terminal from one set of the batteries is connected to the positive terminal of the other set. This system provides 24 volts and 800 amps. This combination is used for cranking large construction equipment.

CAUTION

Use extreme care when jump starting is required. Hooking up jumper cables from a 24-volt system to a heavy-duty 12-volt system can cause severe battery damage, starter destruction, or even an explosion. If you are unsure of the starting circuit, get help from the mechanic field crew for assistance.

LIGHTING SYSTEM

The lighting system on automotive, construction, and weight-handling equipment includes the lamps and bulbs, clearance lights, side marker lights, reflectors, taillights and brake lights, auxiliary lights, and fuses. Standards for lights on vehicles are outlined in the *Federal Motor Carrier Safety Regulations Pocketbook.*

The manufacturer provides equipment with an electrical system that supports the lighting circuits. Part of your prestart responsibility is to ensure the lights on your equipment work and are clean of dust and dirt. A

good rule of thumb to remember is, if a light is on a vehicle, the light must work and be safe.

Lamps and Bulbs

Trucks and buses are lit up like Christmas trees when operating at night. In addition to the headlights and taillights, which are the minimum running lights required bylaw for all vehicles operating at night, trucks and buses must also have clearance and side marker lights. These lights outline the length, height, and width of the vehicle.

Each group of lights in a branch circuit of the lighting system is protected by a fuse or circuit breaker and is provided with a switch. Each light in the group is provided with one or more light bulbs that are rated for the particular circuit.

Light bulbs used in Navy equipment are made to operate on a low-voltage current of 12 or 24 volts, depending upon the voltage of the battery system used. Bulbs are rated as to size by the candlepower of light they produce. They range from small one-half candlepower to large 50-candlepower headlight bulbs. The greater the candlepower of the bulb, the more current it requires when lighted. Bulbs are identified by a number on the base.

Operators are responsible for replacing burned-out bulbs on equipment. Manufacturers have designed bulbs with such a wide variety of designs (fig. 4-4) that it is impossible to list all the bulbs here. A bulb design commonly used has either single or double contacts with nibs to fit bayonet sockets, as shown in figure 4-5. Because of some unique designs, certain bulbs have to be handled with care; for example, quartz bulbs should not be touched by the oil in your skin, because the oil causes the bulb to fail instantly. Because of the unique characteristics of the various bulbs, you should check the operator's manual before replacing any bulbs.

The sealed beam light is actually a large bulb (fig. 4-6). The bulb consists of a lens, filaments, and a glass reflects. Sealed bulbs also have various designs; some have filaments designed for high beam, some with one filament designed for low beam, and bulbs with two filaments designed for high and low beam.

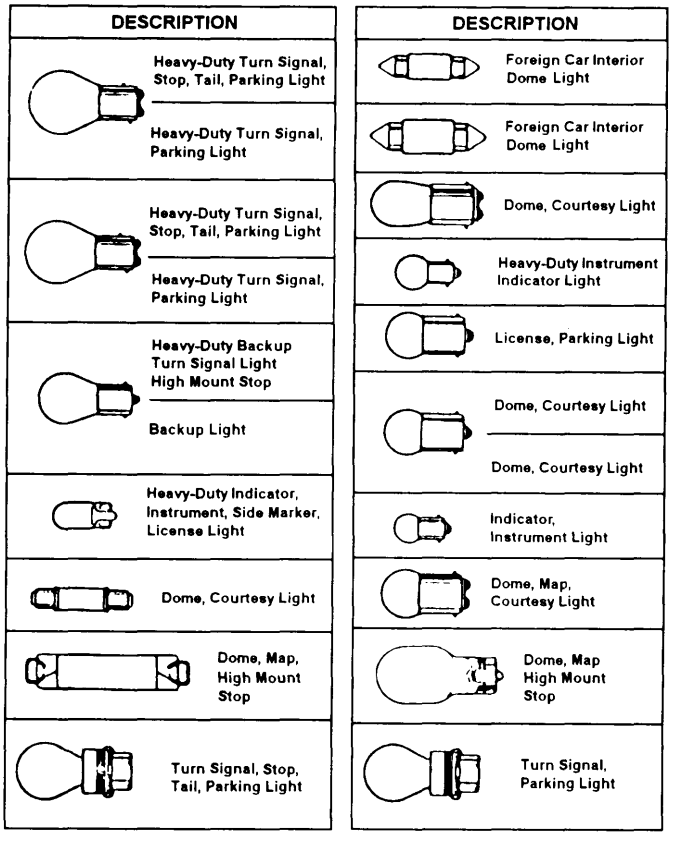

Figure 4-4.—Bulbs.

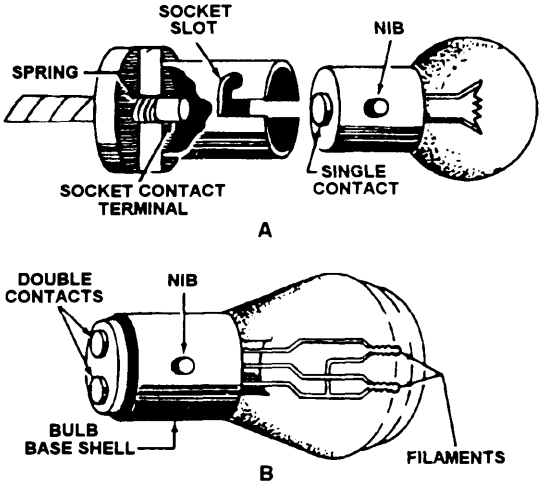

Figure 4-5.—Single- and double-contact bulbs.

Clearance Lights

Clearance lights detail the maximum width of the vehicle, not necessarily its height as the word ***clearance*** implies. These lights highlight the protruding unlighted front and rear corners of the vehicle that are subject to collision with other vehicles or persons, not the top of the vehicle. Clearance lights should be mounted at a height best suited to allow them to be readily seen from a minimum distance of 500 feet from the vehicle. The clearance light on the front of a vehicle should be amber in color, and those facing the rear red. Some state regulations require that larger vehicles have **identification**

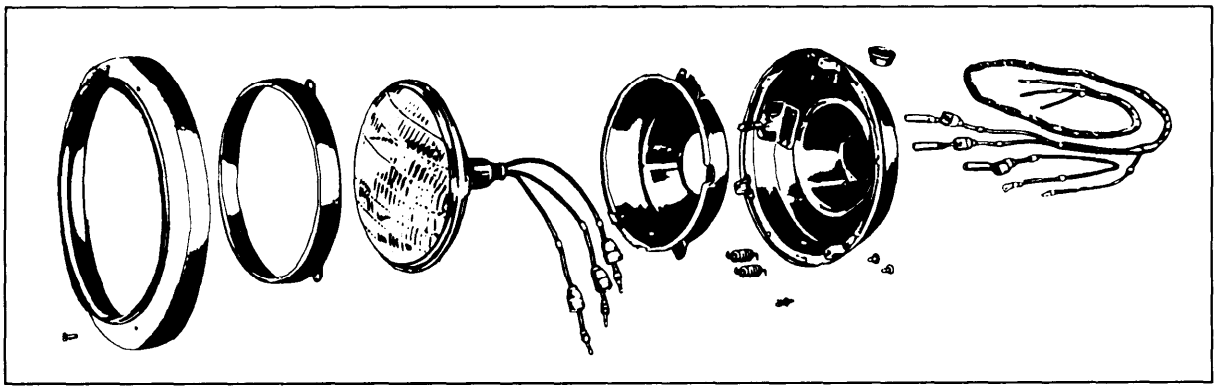

Figure 4-6.—Typical sealed beam headlight assembly.

lights that outlines the height of the vehicle. Some vehicles have a separate switch for the clearance lights. When you are operating a vehicle at night with clearance lights, do not forget to turn them on.

Side Marker Lights

Side marker lights are similar to clearance lights; however; they indicate the full-overall length of the vehicle as viewed from the side. They must also be visible from a minimum distance of 500 feet from the vehicle. Side marker lights, mounted near the front of the vehicle, are also amber and those near the rear are red.

Reflectors

Reflectors (except for those used in the lights) are used as an additional safety precaution in case lights burn out or are broken. When mounting reflectors, ensure they are between 24 to 42 inches above the ground.

Taillights and Brake Lights

All taillights must show red and be visible from at least 500 feet from the rear of the vehicle. The taillight lens should be replaced if it is not red or contains a dot of another color or if it is cracked, broken, or does not fit tightly. A brake light is usually combined with the taillight by using a double-contact, double-filament bulb; however, it maybe a separate light. Stop lights must light up immediately when the brake pedal is depressed; that is, at the beginning of the downward action of the brake pedal. Brake lights are a safety-required item and they must be operational at all times. Burnt-out or weak lights should be documented and repaired before operating your vehicle or piece of equipment.

Auxiliary Lights

Lights that can be turned on or off for the convenience or safety of the driver or passengers are called auxiliary lights. These lights are wired to be turned on and off independently, and not with the headlights. When performing your prestart operation, you should ensure all auxiliary lights work.

SPOTLIGHTS.— Spotlights are often mounted on construction equipment and weight-handling equipment. When conducting prestart operations, always make sure the spot-lights work because you never know when you will encounter conditions or situations requiring their use.

BACKUP LIGHTS.— Backup lights are accessories for many vehicles. They may be mounted singly or as a pair, one on each side. Backup lights lenses must be colorless and must turnoff automatically when the vehicle is moving forward. Backup lights may also be connected to a audible signal. A backup light must be aimed to strike the road at a distance that does not exceed 25 feet from the rear of the vehicle.

PARKING LIGHTS.— Parking lights have amber or white lenses and are located on the front of the vehicle. They turn on and off with the same switch as the taillights.

Fuses

Fuses are safety devices placed in electrical circuits to protect wires and electrical units from a heavy flow of current. Each circuit, or at least each individual

electrical system, is provided with a fuse that has an ampere rating for the maximum current required to operate the unit.

The fuse element is made from a metal that has a low-melting point and is the weakest point in the electrical circuit. In case of a short circuit or other trouble, the fuse burns out first and this opens the circuit just as a switch would do. Visual examination of a burned-out fuse usually provides a quick indication of the problem. A discolored sight glass indicates the circuit has a short either in the wiring or one of its components. If the glass is clear, the problem may be an overload in the circuit.

When replacing a fuse, you should ensure that it has a rating equal to the one burned out. Also, ensure that the malfunction that caused the failure has been determined and repaired.

GAUGES

Just because everything checks out okay during the prestart operation does not mean it will stay that way throughout the workday. You must continually monitor certain conditions, such as water temperature, oil pressure, and so forth, to ensure the equipment is running correctly. You monitor them by watching the indicator (warning lights or gauges) on your equipment. On equipment, you may see an analog type of gauge (fig. 4-7) or color-coded indicators, as shown in figure 4-8.

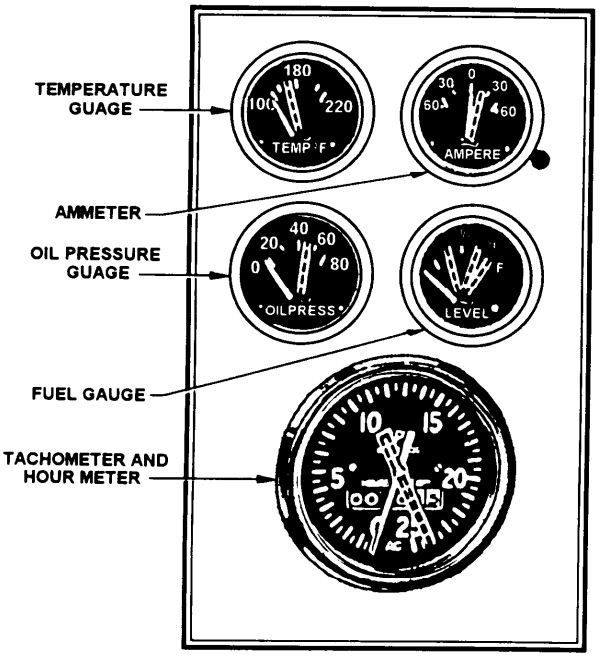

Figure 4-7.—Analog gauges.

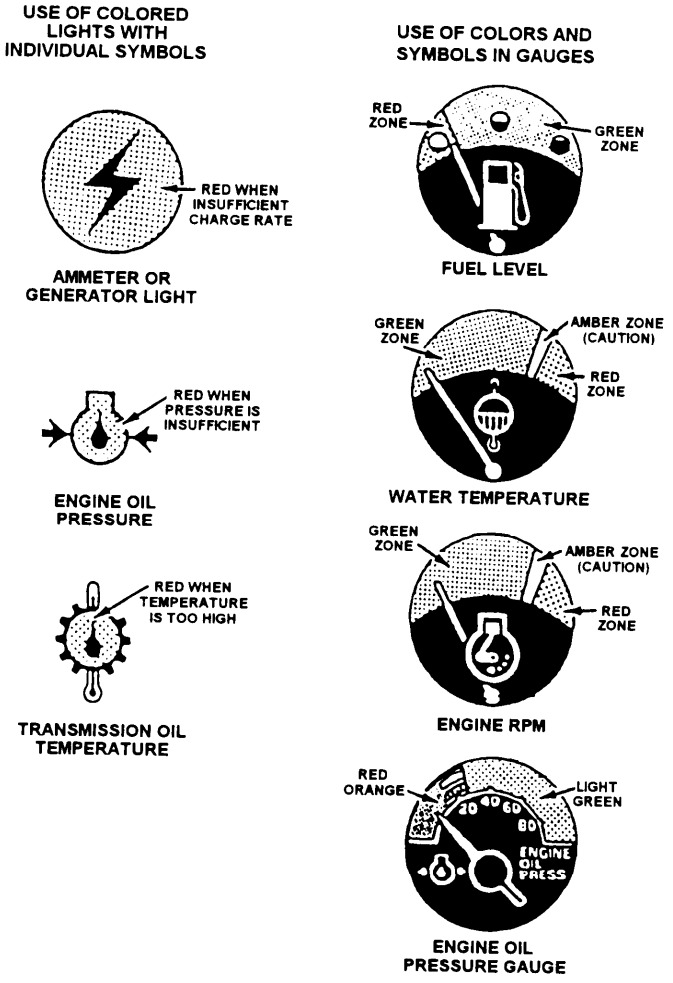

Figure 4-8.-Color-coded gauges.

Water Temperature Gauge

When operating a piece of equipment, you must monitor the water or coolant temperature gauge. If your machine has an analog type of gauge (fig. 4-7), you must know the correct operating temperature. Refer to the operator's manual to determine the operating temperature. Anytime the temperature reading on the gauge starts to rise, stop and determine the reason. Do not wait until the gauge is in the red zone to investigate.

WARNING

Use extreme caution when removing a hot radiator cap. Steam coming from the radiator will cause severe burns.

CAUTION

Do not add cold water to a hot engine when it is not running. Rapid cooling of an overheated engine will cause severe damage to the cylinder head and block. To cool an overheated engine down, leave the engine running and add water slowly. Watch for the steam that may be produced when adding water. Should a radiator hose burst, secure the engine before the temperature gets too high.

Oil Pressure Gauge

The oil pressure indicator is one of, if not, the most important gauges to watch. Every vehicle or equipment has an oil pressure warning light or a gauge. Should you start to lose oil pressure and the warning light comes on, secure the engine immediately. Operating equipment without proper oil pressure causes severe damage to the engine.

Check the oil level in the engine. If the oil level is low, add oil until it is at the proper level. Start the engine; if oil pressure does not register on the gauge or the light stays on for 30 seconds, secure the engine. Then document and report the problem.

Should the oil level be correct and no pressure registers on the gauge or the warning light stays on, secure the engine. Then document and report the problem.

NOTE: A rule of thumb is that after starting an engine, the oil pressure gauge should show 30 pounds of oil pressure after the engine runs for 30 seconds. Should the oil level be correct but no pressure registers on the gauge, secure the engine. Then document and report the problem.

Air Pressure Gauge

There is an air pressure gauge on each vehicle equipped with an air-brake system. The air pressure must be maintained within a range of 100 pounds per square inch (psi) to 120 psi. A warning light or buzzer should come on if the air pressure drops below 60 psi. If there is a rapid loss of air pressure, an air unit may have burst. A slow leak may sometimes be repaired by tightening a fitting.

WARNING

Do not operate any equipment with air brakes if there is an air leak.

With the engine at operating rpm, the air pressure system should build from 85 to 100 psi within 45 seconds in dual-air systems. In single-air systems (pre-1975), the pressure should build up from 50 to 90 psi within 3 minutes.

Hydraulic Pressure Gauge

Most types of construction equipment are equipped with hydraulic pressure guages. When operating this equipment, you must watch for leaks. Consult the operator's manual for the pressure at which the equipment should be operated. Should the pressure not reach the operating range or should you detect a leak, be sure to document and report either or both.

Hydraulic Temperature Gauge

Most types of construction equipment are also equipped with hydraulic temperature gauges. In most cases, if the hydraulic temperature exceeds the recommended temperature, it is because the fluid level is 100 low.

Should the fluid level be correct and the equipment overheats, you are overworking the hydraulic system. Stop your machine and check the hydraulic fluid level. Be careful because the hydraulic fluid is hot and the hydraulic system may be pressurized. If the fluid level is normal, let the machine sit at idle to cool the hydraulics.

Fuel Level Gauge

When prestart inspecting a piece of equipment, you should visually check the fuel. During the day, watch the fuel gauge to ensure it shows a slow depletion of fuel. Should the fuel gauge not move in a reasonable amount of time, assume the fuel gauge is broken. In this case, check the fuel visually from time to time to ensure that you do not run out of fuel.

HYDRAULIC SYSTEMS

Hydraulic systems on equipment are used to transmit power for steering and controlling the operation of mechanical components. The basic components of a

hydraulic system (fig. 4-9) consist of a reservoir, strainer and falters, pump, control valves, hydraulic cylinders, hoses, couplers, accumulators, and on some systems, a hydraulic motor.

HYDRAULIC RESERVOIR

The hydraulic reservoir is the fluid storehouse for the hydraulic system. It contains enough fluid to supply the normal operating needs of the hydraulic system and an additional supply to replace fluid lost through minor leaks. Additionally, the reservoir allows the settling of any impurities and separation of air from the fluid before reuse in the system.

The basic hydraulic reservoir (fig. 4-10) has a space above the fluid even when they are full. This space allows the fluid to foam, and thus purge itself of air

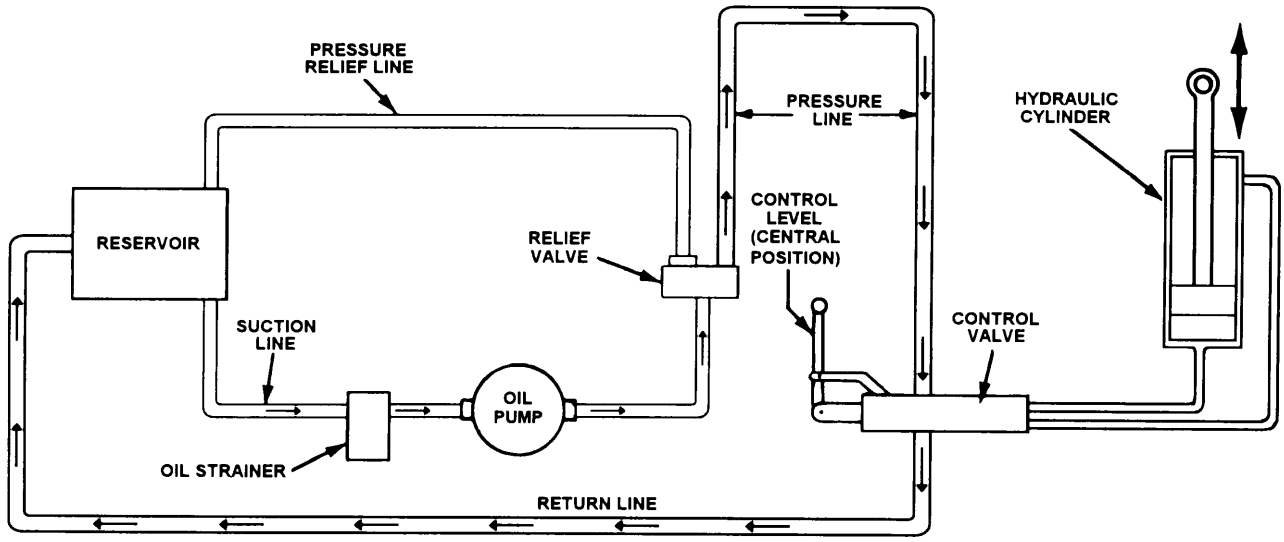

Figure 4-9.-Basic hydraulic system.

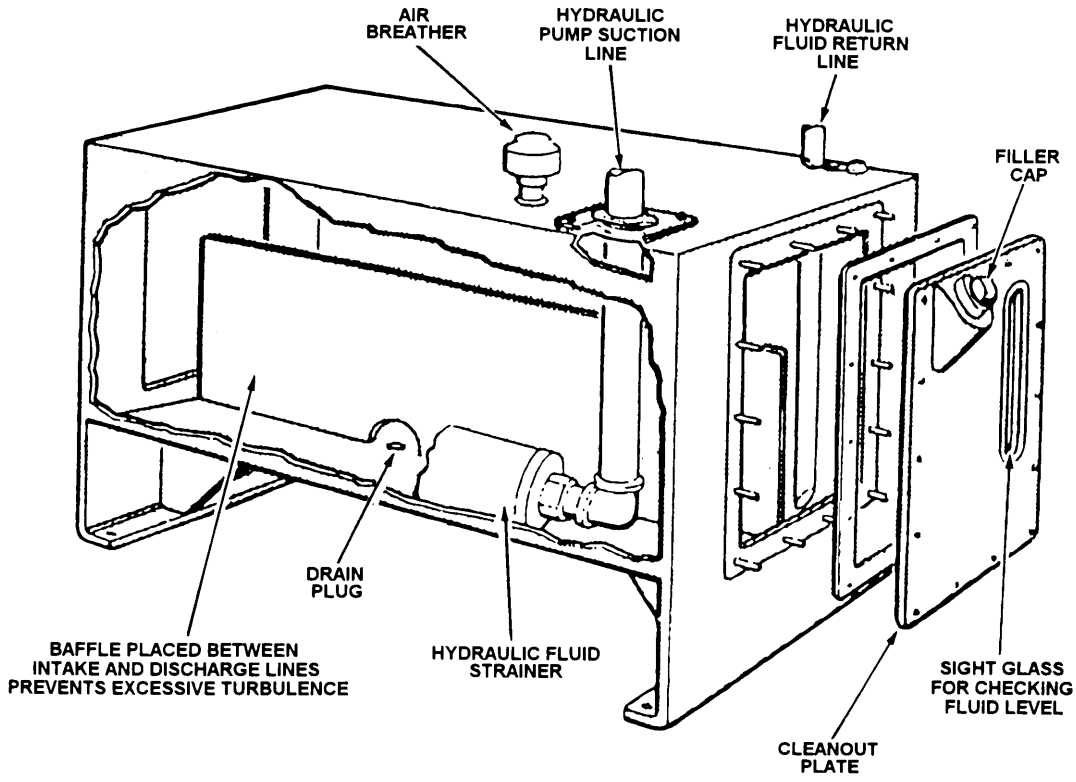

Figure 4-10.—Basic hydraulic reservoir.

bubbles that normally occur as the fluid flows from the reservoir, through the system, and back to the reservoir.

The air vent allows the air to be drawn in and pushed out of the reservoir by the ever-changing fluid level. An air filter is attached to the air vent to prevent drawing atmospheric dust into the system.

Because it is essential that the fluid in the reservoir be kept at the correct level at all times, the sight gauge is provided to allow the normal fluid level to always be seen The baffle plate segregates the outlet fluid from the inlet. This allows the fluid time to dissipate air bubbles, contaminants to settle, and the return fluid to cool before it is picked up by the pump.

The proper hydraulic fluid level must be maintained. In some systems low fluid level causes overheating because the fluid does not have enough time to cool in the reservoir before it gas back into the pump. Also, some systems will not work at all because the fluid is so low in the reservoir that air gets into the pump.

Before adding hydraulic fluid, know what type to use and make sure it is clean. Clean around the filler cap or tube so there is less chance that dirt can get into the system.

STRAINERS AND FILTERS

Hydraulic systems have a strainer and one or more filters that remove the impurities that would eventually contaminate the hydraulic fluid. The strainer is normally located in the reservoir or in the inlet line to the pump. The filter is normally located so only a small amount of fluid is lost when the element is changed. The falter is equipped with a valve that allows the fluid to bypass the filter element should it become clogged. The falter element is usually of the paper cartridge, canister, or edge type and is similar to those used in engine lubrication systems. Regular filter maintenance, performed by the mechanics, is necessary to prevent contaminated fluid from being recirculated in the system.

HYDRAULIC PUMPS

The hydraulic pump creates the flow of fluid within the hydraulic system. The pressure in a hydraulic system is caused by a restriction placed in the path of the fluid as it leaves the pump. Because of the resulting mechanical drive and positive displacement, the pump merely moves the fluid regardless of the restriction. When enough pressure is built up, movement of the restriction occurs or a relief valve placed in the system opens, allowing the fluid to return to the reservoir or the suction side of the pump.

When the pump operates, hydraulic fluid is trapped between the gear teeth and the pump housing and is carried to the outlet side of the pump. As the teeth mesh, a seal is freed by the mating surfaces that prevent the oil from leaking back to the inlet side of the pump. The sealing action causes the oil to be forced out of the pump and into the system.

CONTROL VALVES

Control valves are valves accessible to the operator for directing the flow of fluid within the system to operate the machine or its attachment. By skillful use of the control valves, the operator can regulate the speed and operation of the hydraulic cylinders.

NOTE: Hydraulic controls should be operated smoothly to eliminate the jerking motion that causes rapid wear and failure of the mechanical parts of the machine.

HYDRAULIC CYLINDERS

Hydraulic cylinders are used to transmit motion in relation to the volume of fluid directed into the cylinder. The force created by the cylinder is determined by the pressure of the fluid and the area of the piston contacted by the fluid. Thus the larger the piston, the more force generated.

Hydraulic cylinders used on heavy equipment are either single- or double-acting cylinders.

Single-Acting Cylinders

Single-acting cylinders, similar to the one shown in figure 4-11, view A, are used to exert force in only one direction. This means the weight or resistance moved must be located so it causes the cylinder to return to its original position when pressure is relieved from the piston. A common use of this type of cylinder is in a hydraulic jack.

Double-Acting Cylinders

Double-acting cylinders are used on equipment where force is needed in two directions. Unlike the single-acting cylinder, the double-acting cylinder contains seals at both ends of the piston where the piston rod passes through the end of the cylinder. With the use of this cylinder, fluid can be directed to either side of the piston and cause the piston rod to extend or retract under

pressure. The double-acting cylinder shown in figure 4-11, view B, is called an unbalanced cylinder. This means that the cylinder can exert more force in one direction than in the other. This is due to the piston rod preventing fluid from acting on the full area of the piston on one side.

NOTE: Wipe off all foreign material from hydraulic rams with a clean rag during pre- and post-operations to prevent damaging seals and wiper seals. Before you store equipment, a very important procedure to remember is that the exposed hydraulic rams on the equipment and attachments should be coated in grease. This action protects the surface of the hydraulic ram and is critical in storage locations where corrosive environmental conditions, such as salty air, strong winds, or blowing sand, exist.

Remember: Wipe off the grease before using the equipment when it is removed from storage.

FLEXIBLE HOSES

Flexible hoses are used in a hydraulic system to allow movement between mechanical parts of the

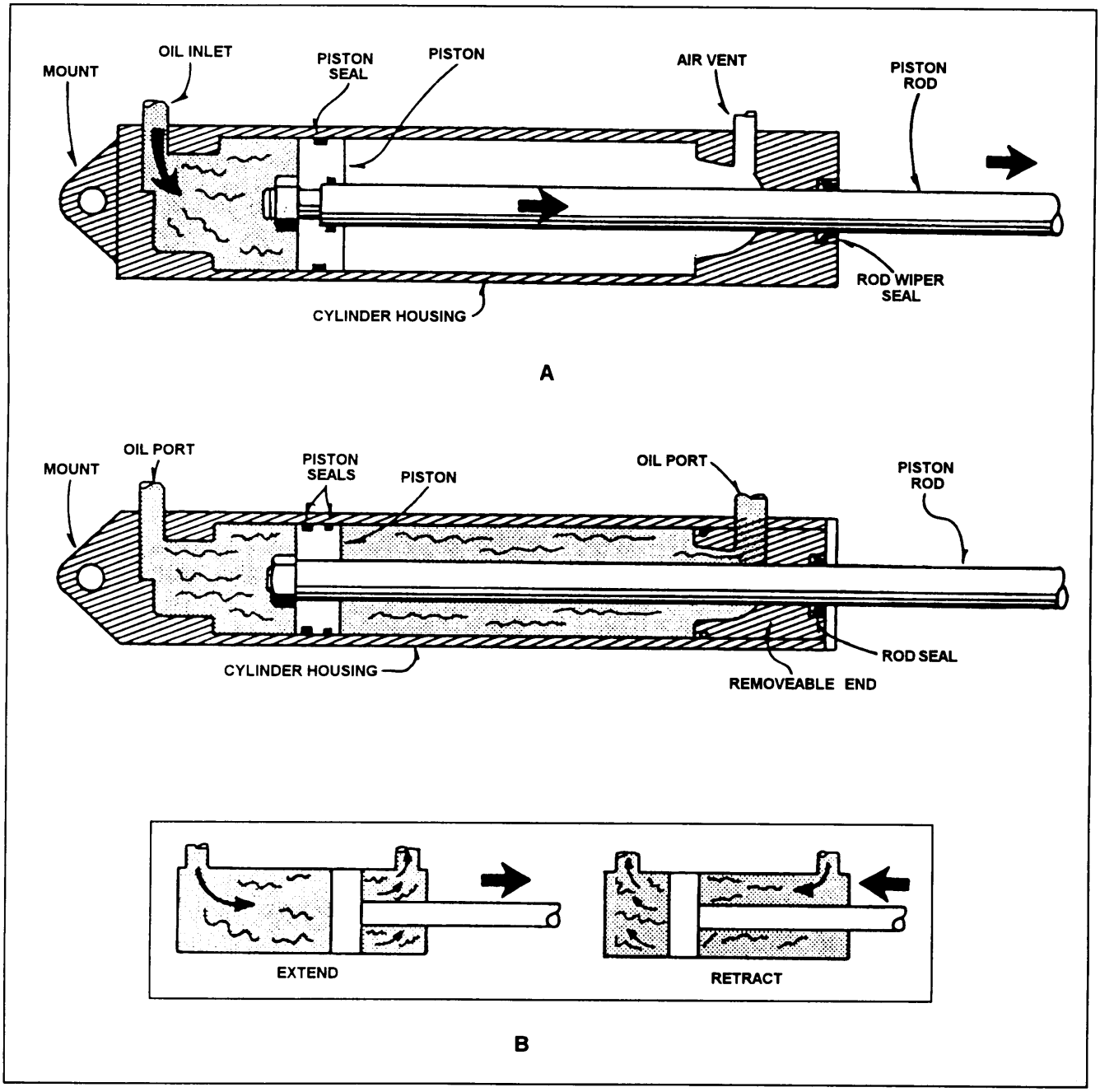

Figure 4-11.—(A) Single- and (B) double-acting hydraulic cylinders.

equipment. Hoses are manufactured in layers (fig. 4-12). The inner layer is made of synthetic materials that resist deterioration from the fluid in the system. The middle layer or layers are made of either fabric or rubber for low-pressure systems or wire braid for high-pressure applications. These layers give the hose its strength.

Part of your pre- and post-operational inspections is to inspect hoses for cracking or splitting, pinhole leaks, improper hose length, rubbing, heat, twisting, and so forth. Any problems with hydraulic hoses should be repaired before use.

QUICK-DISCONNECT COUPLERS

Quick-disconnect couplers (fig. 4-13) are used where hydraulic lines must be connected or disconnected frequently; for example, in the NCF, quick-disconnect couplers used on front-end loaders allow quick changing of loader buckets, backhoes, and forklift attachments.

The quick-disconnect couplers are self-sealing devices that accomplish the work of two shutoff valves and a tube coupler. They are easy to use and keep hydraulic fluid loss at a minimum. More importantly, you do not have to drain or bleed the system each time a hookup is made.

Quick-disconnect couplers consist of two halves: the body contains a spring-loaded poppet or seal, while the other half is inserted to open the poppet when the two halves are connected. A locking device holds the two halves and seals them.

When quick-disconnect couplers are disconnected on attachments, you must remember that it is *very important* that dust plugs are inserted in the coupler ports. If dust plugs are unavailable, a common practice is to use a plastic bag to wrap the couplers in for protection from foreign matter.

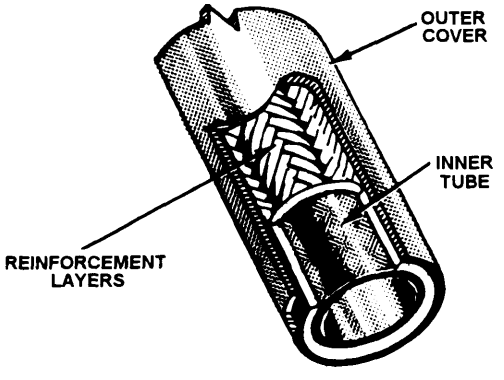

Figure 4-12.—Hydraulic hose construction.

CAUTION

Hydraulic systems can create up to 3,000 pounds of pressure per square inch and the fluids may reach temperatures above 200°F. Wear protective gloves and use extreme care when disconnecting and reconnecting quick-disconnect couplers.

ACCUMULATORS

Accumulators are sometimes placed in a hydraulic system to absorb shock. These are frequently used on

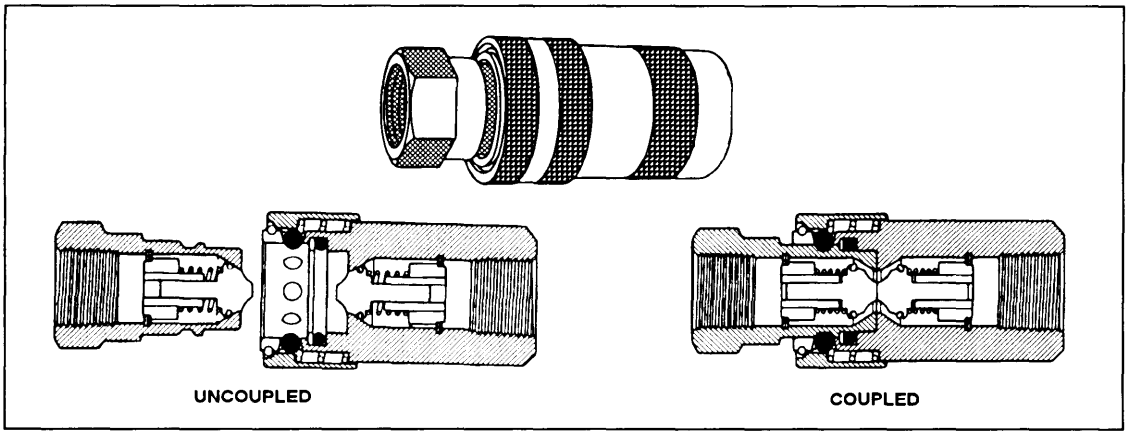

Figure 4-13.—Quick-disconnect couplers.

tracked front-end loaders and other equipment containing hydraulic systems that are subjected to severe shock.

The accumulator is a large cylinder that contains compressed gas or a coil spring separated from the hydraulic fluid by a piston, rubber bladder, or diaphragm. When a heavy shock is placed on the hydraulic system, fluid enters the cylinder and causes the gas or spring to compress. Once the shock load stabilizes within the hydraulic system, the fluid is forced back to the operating portion of the system.

HYDRAULIC MOTORS

The hydraulic motor provides power to winches on cranes, drives conveyors on ditching machines, and is used in other applications where mechanical drives are impractical.

The hydraulic motor is turned by fluid under pressure supplied by the pump. The fluid enters the housing and acts on the rotating members. It then discharges and returns to the reservoir or pump.